

CLAIMS

1 1. A laser apparatus for creating visible surface deformations on the surface of a
 2 workpiece such as a multi-layered workpiece including an upper carbon layer, at least
 3 one intermediate metallic layer, and a lower substrate, comprising:
 4 (a) a laser generator for generating an output laser beam;
 5 (b) a beam conditioner responsive to said output laser beam and operative to
 6 generate a conditioned laser beam, said beam conditioner including (i) a beam
 7 expander responsive to said output laser beam and operative to generate an expanded
 8 laser beam and (ii) a variable beam attenuator responsive to said expanded laser
 9 beam and operative to generate a conditioned marking beam;
 10 (c) a beam steerer for directing said marking beam to a surface of a workpiece;
 11 and
 12 (d) a materials handler for positioning said workpiece in the path of said marking
 13 beam.

1 2 A laser apparatus as recited in Claim 1 wherein said variable beam attenuator
 2 includes a first optical plate responsive to said expanded laser beam and operative to
 3 generate a conditioned laser beam; and a beamsplitter responsive to said conditioned
 4 laser beam and operative to split said conditioned laser beam into a plurality of beams
 5 including said marking beam.

1 3. A laser apparatus as recited in Claim 2 wherein said first optical plate is
 2 rotatable along an axis parallel to that of said laser beam and operative to vary the
 3 fluence of said marking beam striking said ^{hard disk}workpiece.

1 4. A laser apparatus as recited in Claim 2 wherein said first optical plate is a half-
 2 wave plate.

1 5. A laser apparatus as recited in Claim 1 wherein further comprising a beam
 2 sampler and a detector, said beam sampler being positioned in the path of said
 3 marking beam and capable of passing a sample of said marking beam to said detector,

4 said detector being capable of receiving said sample and generating a signal
5 responsive to the fluence of said marking beam.

1 6. A laser apparatus as recited in Claim 1 wherein said variable beam attenuator
2 includes a beamsplitter, and wherein said apparatus further comprises an optical
3 isolator for optically isolating the laser generator from any reflection of said marking
4 beam to said laser generator, said optical isolator including a second optical plate
5 positioned in the path of said marking beam, whereby the polarization plane of any
6 reflection of the marking beam is rotated such that the reflection exits the beamsplitter
7 in a direction away from said laser beam generator.

1 7. A laser apparatus as recited in Claim 6 wherein said second optical plate is a
2 quarter-wave plate.

1 8. A laser apparatus as recited in Claim 1 wherein said laser generator includes a
2 Q-switched diode-pumped laser.

1 9. A laser apparatus as recited in Claim 1 further comprising a processor capable
2 of receiving one or more signals responsive to one or more of variables from the group
3 consisting of the status of said laser generator, the pattern of marks to be placed on
4 said ^{hard disk}workpiece, the direction of said selected beam leaving said beam steerer, and the
5 position of the ^{hard disk}workpiece relative to the beam steerer, said processor being capable of
6 generating one or more signals affecting the status of said laser generator, the desired
7 pattern of marks to be made on the surface of said ^{hard disk}workpiece, the direction of the
8 beam leaving the beam steerer, or the position of the ^{hard disk}workpiece to be marked.

1 10. A laser apparatus as recited in Claim 1 wherein said laser generator is operated
2 in a pre-lasing mode.

1 11. A laser apparatus as recited in Claim 1 wherein said selected beam is scanned
2 across a portion of the surface of said workpiece to form deformations therein in a
3 predetermined pattern.

1 12. A laser apparatus as recited in Claim 11 wherein the resolution of said pattern is
2 determined by varying the size of the beam from said beam conditioner.

1 13. A laser apparatus as recited in Claim 11 wherein said laser beam is in pulses,
2 and the contrast of said pattern is varied by changing one or more of the group
3 consisting of pulse energy, pulse frequency and laser beam scanning speed.

1 14. A method for creating a surface deformation on the surface of a workpiece such
2 as a multi-layered workpiece including a substrate, a first layer placed over said
3 substrate and having a first melting point, one or more additional layers placed over
4 said first layer and having melting points higher than said first melting point, and a
5 protective layer placed over said additional layers, said method comprising the steps
6 of:

- 7 (a) generating a laser beam;
8 (b) expanding said laser beam to a predetermined diameter;
9 (c) attenuating the expanded beam to a level suitable for creating said surface
10 deformation.
11 (d) passing the attenuated beam to a beam steerer to produce an output
12 marking beam;
13 (e) positioning said workpiece in the path of said marking beam;
14 (f) creating one or more deformations on a surface of said workpiece by
15 scanning said marking beam over said surface.

1 15. A method as recited in Claim 14 wherein said expanded beam is attenuated by
2 passing said expanded beam through a first optical plate and passing the output from
3 said first optical plate through an optical device responsive to said first optical plate,
4 thus producing said attenuated beam.

1 16. A method as recited in Claim 15 wherein said first optical plate is rotatable along
2 an axis parallel to that of said laser beam and operative to attenuate said marking
3 beam.

1 17. A method as recited in Claim 15 wherein said optical device is a beamsplitter
2 operative to produce a plurality of beams, including said attenuated beam.

1 18. A method as recited in Claim 15 further comprising optically isolating said laser
2 generator from said workpiece by positioning a second optical plate in the path of said
3 attenuated beam.

1 19. A method as recited in Claim 18 wherein said first optical plate is a half-wave plate
2 and said second optical plate is a quarter-wave plate.

1 20. A method as recited in Claim 14 further comprising taking a sample of said
2 attenuated beam, determining the fluence of said attenuated beam from said sample,
3 and generating a signal responsive to said fluence.

1 21. A method as recited in Claim 14 further comprising using a processor to obtain
2 signals responsive to the status of one or more of the group consisting of laser beam
3 on/off status, position of the beam steerer, and position of the workpiece, and to
4 generate one or more signals to control one or more of the group consisting of the
5 frequency, fluence, spot size, on/off status and scanning speed of said marking beam,
6 and movement of said marking beam relative to said workpiece.

1 22. A method as recited in Claim 21 further comprising forming said deformations in
2 a predetermined pattern on a portion of said surface of said workpiece by inputting a
3 predetermined pattern into said processor and using the processor to control scanning
4 said marking beam over said portion.

1 23. A method as recited in Claim 22 further comprising forming said deformation by
2 melting said first layer while substantially maintaining the integrity of said protective
3 layer.

1 24. A method as recited in Claim 14 further comprising forming a pattern of
2 deformations on a portion of said surface by controlling one or more of the group
3 consisting of the frequency, fluence, spot size, and on/off of said marking beam, and

4 the scanning speed and relative position of said marking beam with respect to the
5 surface of said workpiece.

1 25. A method as recited in Claim 14 wherein said laser beam is generated by a
2 diode-pumped laser.

1 26. A method as recited in Claim 25 wherein said laser is operated in a pre-lasing
2 mode.

1 27. A method as recited in Claim 25 wherein said laser beam is pulsed, the beam
2 pulses being formed by a Q-switch operating said laser.

1 28. A workpiece having a surface marked by selectively located deformations and
2 including a substrate, a first layer adjacent to said substrate and having a first melting
3 point, one or more additional layers, at least one of which is adjacent to said first layer,
4 said additional layers having melting points substantially above said first melting point,
5 and an outer protective layer adjacent to the outermost of said additional layers, the
6 surface of said workpiece having laser-induced visible surface deformations and a
7 substantially intact protective layer over said deformations, said deformations being
8 formed by a method which comprises the steps of

9 ((a) generating a laser beam;

10 (b) expanding said laser beam to a predetermined diameter;

11 (c) attenuating the expanded beam to a level suitable for creating said surface
12 deformation.

13 (d) passing the attenuated beam to a beam steerer to produce an output
14 marking beam;

15 (e) positioning said workpiece in the path of said marking beam;

16 (f) creating one or more deformations on a surface of said workpiece by scanning said
17 marking beam over said surface.

1 29. A workpiece as recited in Claim 28 wherein said expanded beam is attenuated
2 by passing said expanded beam through a first optical plate and passing the output

3 from said first optical plate through an optical device responsive to said first optical
4 plate, thus producing said attenuated beam.

1 30. A workpiece as recited in Claim 29 wherein said first optical plate is rotatable
2 along an axis parallel to that of said laser beam and operative to attenuatesaid marking
3 beam.

1 31. A workpiece as recited in Claim 29 wherein said optical device is a beamsplitter
2 operative to produce a plurality of beams, including said attenuated beam.

1 32 A workpiece as recited in Claim 28 wherein said laser generator is optically
2 isolated from said workpiece by positioning a second optical plate in the path of said
3 attenuated beam.

1 33. A workpiece as recited in Claim 32 wherein said first optical plate is a half-wave
2 plate and said second optical plate is a quarter-wave plate.

1 34. A workpiece as recited in Claim 28 further comprising maintaining said
2 workpiece at a predetermined location with respect to said beam steerer during said
3 scanning.

1 35. A workpiece as recited in Claim 28 wherein said marking beam is pulsed and
2 has a fluence of about 0.8 Joule/square centimeter, a wavelength of 1064 nanometer,
3 and a pulse duration of about 50 nanoseconds.

1 36. A workpiece as recited in Claim 28 wherein said laser beam is generated by a
2 diode - pumped laser.

1 37. A workpiece as recited in Claim 28 wherein said workpiece is a magnetic media
2 hard disk, said first layer including nickel-phosphorous, said additional layers including
3 a chromium layer and a magnetic layer, and said protective layer including carbon, said
4 workpiece also containing a surface lubricant adjacent to said protective layer.

1 38. A workpiece as recited in Claim 37 wherein said disk is a clean finished disk.

1 39. A workpiece as recited in Claim 28 wherein said deformation is produced by
2 laser-induced melting and subsequent resolidification of said first layer while
3 maintaining the integrity of said carbon layer.

1 40. In a method for making a workpiece having visible surface marking, said
2 workpiece having multiple layers including a substrate, a first layer with a first melting
3 point adjacent to said substrate, one or more additional layers at least one of which is
4 adjacent to said first layer, said additional layers having melting points substantially
5 above said first melting point, and a protective layer adjacent to the outermost of said
6 additional layers, the improvement comprising: creating said surface marking by
7 melting said first layer while leaving said protective layer substantially intact by using a
8 laser beam having a wavelength within the range of about 400 to about 10,000
9 nanometers, a pulse duration within the range of about 30 to about 120 nanoseconds,
10 a pulse frequency from about 1 to about 100 kilohertz, a laser fluence from about 0.5 to
11 about 1.5 Joules/square centimeter, and a laser spot size diameter from about 10 to
12 about 30 micrometers.

1 41. A method for making a workpiece as recited in Claim 40 wherein said laser
2 beam has a fluence of about 0.8 Joule/square centimeter, a wavelength of 1064
3 nanometers, and a pulse duration of about 50-nanoseconds.

1 42. A workpiece having visible surface marking and multiple layers including a
2 substrate, a first layer adjacent to said substrate having a first melting point, one or
3 more additional layers at least one of which is adjacent to said first layer and with
4 melting points substantially above said first melting point, and a protective layer
5 adjacent to the outermost of said additional layers, said markings being formed by
6 melting said first layer while leaving said protective layer substantially intact by using a
7 laser beam having a wavelength within the range of about 400 to about 10,000
8 nanometers, a pulse duration within the range of about 30 to about 120 nanoseconds,
9 a pulse frequency from about 1 to about 100 kilohertz, a laser fluence from about 0.5 to

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